

and meteoroids, and will determine their velocity and size distributions around the spacecraft environment. With two different color diode lasers, the contaminant and meteoroid composition will also be determined based on laboratory calibration with different materials. Secondary particles dislodged from the top aluminum surface of the MOS detector will also be measured to determine the kinetic energy losses during energetic meteoroid impacts. The velocity range of this instrument is 0.1 m/s to more than 14 km/s, while its size sensitivity is from 0.2  $\mu\text{m}$  to millimeter-sized particles.

The particulate measurements in space of the kind proposed here will be the first simultaneous multipurpose particulate experiment that includes velocities from very slow to hypervelocities, sizes from submicrometer- to pellet-sized diameters, chemical analysis of the particulate composition, and measurements of the kinetic energy losses after energetic impacts of meteoroids.

This experiment will provide contamination particles and orbital debris data that are critically needed for our present understanding of the space environment. The data will also be used to validate contamination and orbital debris models for predicting optimal configurations of future space sensors and for understanding their effects on sensitive surfaces such as mirrors, lenses, paints and thermal blankets.

**OPTIMISM EXPERIMENT AND DEVELOPMENT OF SPACE-QUALIFIED SEISMOMETERS IN FRANCE.** P. Lognonné<sup>1</sup>, J. F. Karczewski<sup>2</sup>, and DT/INSU-CRG Garchy Team<sup>2</sup>, <sup>1</sup>IPGP, 4 Place Jussieu, 75252 Paris Cedex 05, France, <sup>2</sup>INSU, 4 Avenue de Neptune, 94107 Saint Maur des Fosses Cedex, France.

The OPTIMISM experiment will put two magnetometers and two seismometers on the martian floor in 1995, within the framework of the Mars '94 mission. The seismometers are put within the two small surface stations.

The seismometer sensitivity will be better than  $10^{-9}$  g at 1 Hz, 2 orders of magnitude higher than the Viking seismometer sensitivity. *A priori* waveform modeling for seismic signals on Mars [1] shows that it will be sufficient to detect quakes with a seismic moment greater than  $10^{15}$  Nm everywhere on Mars. Such events, according to the hypothesis of a thermoelastic cooling of the martian lithosphere, are expected to occur at a rate close to one per week [2] and may therefore be observed within the 1-year lifetime of the experiment.

Due to severe constraints on the available power, mass budget, g load, and size of the small stations, it was necessary to completely redesign the seismometer sensors and electronic. The sensor has been developed in order to support a high g load of 200 g/10 ms without reducing its sensitivity. It consists of a new leaf-spring vertical seismometer, with a free period close to 0.5 s and an inertial mass of 50 g. The seismometer has two modes, working either with a velocity transducer, for high-frequency seismic measurements, or with a displacement transducer, for long-period seismic measurements. The seismometer's mass is 340 g, and its size is 9 cm<sup>3</sup>.

Along the same lines, a low-power, hybrid technology has been used for the electronic. The velocity transducer and displacement transducer need a power of a few milliwatts, with a sensitivity of  $10^{-10}$  for the displacement transducer.

This seismometer will be the first space-qualified or automatic very-broad-band seismometer to be developed in France. The next generation will consist of a triaxial seismometer, with performances

at least 1 order of magnitude better than the OPTIMISM seismometer.

**References:** [1] Lognonné and Mosser (1992). [2] Solomon et al. (1991).

**FILTERING INTERPOLATORS FOR IMAGE COMPARISON ALGORITHMS.** R. L. Lucke<sup>1</sup> and A. D. Stocker<sup>2</sup>, <sup>1</sup>Code 7604, Naval Research Laboratory, Washington DC 20375-5352, USA, <sup>2</sup>Space Computer Corporation, Suite 104, 2800 Olympic Boulevard, Santa Monica CA 90404-4119, USA.

Comparing two or more images, either by differencing or ratioing, is important to many remote sensing problems. Because the pixel sample points for the images are (almost) always separated by some nonzero shift, a resampling, or interpolation, process must be performed if one image is to be accurately compared to another. Considered in Fourier space, an interpolator acts as a filter that attenuates some frequencies (usually high) of the image. Thus, when the shifted and unshifted images are compared, the former has been filtered, while the latter has not; the effect of this difference is called interpolation error. The key idea of this paper is to apply a filter to the unshifted image that matches the filtering effect of applying the interpolator to the shifted image, thereby drastically reducing interpolation error. The resulting interpolators, called filtering interpolators, are derived and discussed in detail elsewhere [1]. Basic results will be given in this presentation.

The cost of reducing interpolation error is some loss of high-frequency information. This paper presents parameterized families of local convolutional interpolators (polynomial and trigonometric) that can be adjusted to the desired trade-off between interpolation error reduction and high-frequency information retention. These interpolators allow as many images as desired, all with different shifts, to be compared on an equal footing.

The method is derived for images with the same pixel spacing and purely translational shifts. Performance suffers if these conditions are not met, but is still better than ordinary interpolation. Four-point interpolators are probably the most useful because they give good interpolation performance with reasonable computational efficiency. One-dimensional formulas are given; for two dimensions, the interpolators are applied to each dimension separately. In tests on simulated imagery, the filtering interpolators reduced interpolation error to below the level of sensor noise for 13-bit data (LSB = rms noise) on highly structured scenes.

**References:** [1] Lucke R. L. and Stocker A. D. (1993) *IEEE Trans. Signal Processing*, in press.

**MASS SPECTROMETRIC MEASUREMENT OF MARTIAN KRYPTON AND XENON ISOTOPIC ABUNDANCE.** P. Mahaffy<sup>1</sup> and K. Mauersberger<sup>2</sup>, <sup>1</sup>Laboratory for Atmospheres, NASA/Goddard Space Flight Center, Greenbelt MD 20771, USA, <sup>2</sup>University of Minnesota, School of Astronomy and Physics, Minneapolis MN 55455, USA.

The Viking gas chromatograph mass spectrometer experiment provided significant data on the atmospheric composition at the surface of Mars, including measurements of several isotope ratios. However, the limited dynamic range of this mass spectrometer resulted in marginal measurements for the important Kr and Xe

isotopic abundance. The  $^{129}\text{Xe}$  to  $^{132}\text{Xe}$  ratio was measured with an uncertainty of 70%, but none of the other isotope ratios for these species were obtained. Accurate measurement of the Xe and Kr isotopic abundance in this atmosphere provides a important data point in testing theories of planetary formation and atmospheric evolution. The measurement is also essential for a stringent test for the martian origin of the SNC meteorites, since the Kr and Xe fractionation pattern seen in gas trapped in glassy nodules of an SNC (EETA 79001) is unlike any other known solar system reservoir. Current flight mass spectrometer designs combined with the new technology of a high-performance vacuum pumping system show promise for a substantial increase in gas throughput and the dynamic range required to accurately measure these trace species.

The wide dynamic range of present space flight mass spectrometer analyzer/detector systems allows ionization pressures to be pushed toward the point where the gas mean free path in the ion source is limiting. However, the fixed capacity of miniaturized high-vacuum pumping systems has put significant constraints on several previous mass spectrometer experiments, including the Viking mass spectrometer. The noble gases are not pumped by chemical pumps and with a very limited capacity by miniaturized ion pumps. In addition, an ion-pumped system can release previously pumped material with a corresponding loss of accuracy.

A recent commercial development in high-vacuum pumping technology is that of wide-range turbomolecular/molecular drag pump hybrids where both stages are attached to the same rotating shaft. The natural exhaust pressure of the molecular drag stage is approximately 10 mbar. Compression ratios of  $10^7$  or higher for N are achieved with very small pumping systems. It is expected that with continued development toward a ruggedized flight pump a mass of less than 1 kg for a system with a pumping speed of 10 to 30 liters/s can readily be achieved. The pump capacity is only limited by power constraints and eventual failure of the bearings after several thousand hours of operation. With reference to the payload described by the MESUR Science Definition Team, a mass spectrometer experiment incorporating such a pump together with a recently developed thermal analyzer [1] could provide information on the volatile composition of martian near-surface solid-phase material in addition to carrying out the isotope measurements described.

References: Mauersberger K. et al. (1992) *LPITech. Rpt. 92-07*.

**VISIBLE IMAGING ON THE PLUTO FAST FLYBY MISSION.** M. C. Malin, Malin Space Science Systems, 3535 General Atomics Court, Suite 250, San Diego CA 92121, USA.

Objectives for visible imaging of the Pluto-Charon system, as prescribed by the Outer Planets Science Working Group, are to acquire (1) global observations (FOV of ~5000 IFOVs) at 1 km/line-pair for the purpose of characterizing surface morphology and geology, (2) global observations in 3-5 broadband colors at 5-10 km/line-pair for studies of surface properties and composition as it relates to morphology, and (3) selected observations at higher spatial resolution for study of surface processes.

Several factors of the Pluto Fast Flyby mission make these difficult objectives to achieve: At Pluto's distance from the Sun, there is nearly 1/1000 the amount of light as at the Earth, the flyby

velocity is high (~15 km/s), and the science requirements dictate a large data volume (1 km/line-pair implies between 20 and 50 MBytes for the panchromatic global image, and a comparable amount for the multispectral dataset).

The low light levels can be addressed through a large aperture, image intensification, long exposures with precision pointing and image motion compensation (scan mirror or spacecraft movement), or time-delay integration. The high flyby velocities require short exposures, image motion compensation, or observations from considerable distance (e.g., longer focal lengths and larger apertures). Large data volume requires a large spacecraft data buffer, an internal instrument data buffer, or real-time data compression. The difficulty facing the successful Pluto Fast Flyby imaging investigation will be overcoming these technical challenges within the extremely limited mass (~2 kg) and power (~2 W) available.

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A DTA/GC FOR THE *IN SITU* IDENTIFICATION OF THE MARTIAN SURFACE MATERIAL. R. L. Mancinelli<sup>1</sup>, M. R. White<sup>1</sup>, and J. B. Orenberg<sup>2</sup>, <sup>1</sup>NASA Ames Research Center, Moffett Field CA 94035, USA, <sup>2</sup>Department of Chemistry and Biochemistry, San Francisco State University, San Francisco CA 94132, USA.

The composition and mineralogy of the martian surface material remain largely unknown. To determine its composition and mineralogy several techniques are being considered for *in situ* analyses of the martian surface material during missions to Mars. These techniques include X-ray fluorescence, X-ray diffraction,  $\alpha$ -proton backscattering,  $\gamma$  ray spectrometry, mass spectrometry, differential thermal analysis (DTA), differential scanning calorimetry (DSC), and pyrolysis gas chromatography. Results of a comparative study of several of these techniques applicable to remote analysis during MESUR-class missions indicate that DTA/GC would provide the most revealing and comprehensive information regarding the mineralogy and composition of the martian surface material [1].

We have successfully developed, constructed, and tested a laboratory DTA/GC. The DTA is a Dupont model 1600 high-temperature DTA coupled with a GC equipped with a MID detector. The system is operated by a Sun Sparc II workstation. When gas evolves during a thermal chemical event, it is shunted into the GC and the temperature is recorded in association with the specific thermal event. We have used this laboratory instrument to define experimental criteria necessary for determining the composition and mineralogy of the martian surface *in situ* (e.g., heating of sample to 1100°C to distinguish clays). Our studies indicate that DTA/GC will provide a broad spectrum of mineralogical and evolved gas data pertinent to exobiology, geochemistry, and geology. Some of the important molecules we have detected include organics (hydrocarbons, amides, amines, etc.),  $\text{CO}_3^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{NO}_2^-$ ,  $\text{NH}_4^+$ ,  $\text{SO}_4^{2-}$ ,  $\text{H}_2\text{O}$ , and  $\text{CO}_2$ . The technique can also discern the mineral character of the sample (i.e., clay vs. silicates vs. glasses; degrees of hydration, etc.) [2]. It is thought that the surface of Mars consists primarily of an amorphous juvenile silicate material similar to palagonite with not more than 15 wt% clay [3]. This type of mixture is easily determined by DTA/GC using the high-temperature (1100°C) capability of the DTA [1,2]. This is important to the definition of mission analytical techniques, which must be able to analyze samples ranging from those containing no clay or evaporites to samples composed of